Stacks

15-213: Introduction to Computer Systems
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Section G

Today: Stacks on stacks on stacks

- News
- Stack discipline review
  - Quick review of registers and assembly
  - Stack frames
  - Function calls (IA32)
  - x86 (IA32) and x86-64
- Example

News

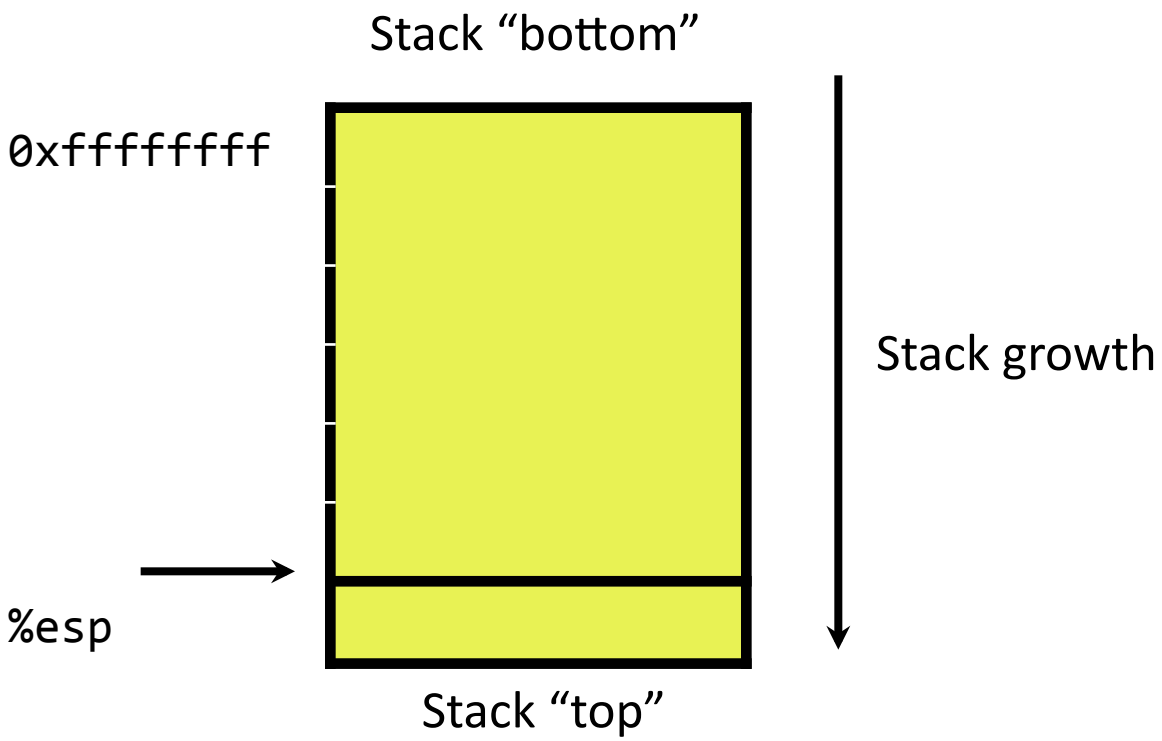
- bomblab is due tomorrow night
  - Don't use your late days yet
  - But "if you wait till the last minute, it only takes a minute!"
- buflab is coming out tomorrow night
  - All about stacks
- Pro-tip: we love stack questions on exams
  - Students find stack questions difficult
  - Make sure you know stacks well

Quick review of registers (IA32)

- Caller saved: %eax, %ecx, %edx
  - You must save these before a function call if you need them
- Callee saved: %ebx, %edi, %esi
  - You must save these before any work if you need them
- Base pointer: %ebp
  - Points to the “bottom” of a stack frame
- Stack pointer: %esp
  - Points to the “top” of a stack frame
- Instruction pointer: %eip
  - Generally don’t need to worry about this one

IA32 stack

- This is a memory region that grows down
- Confusingly, refer to the bottom of the stack as the "top"
- %esp refers to the lowest stack address



pushing and popping

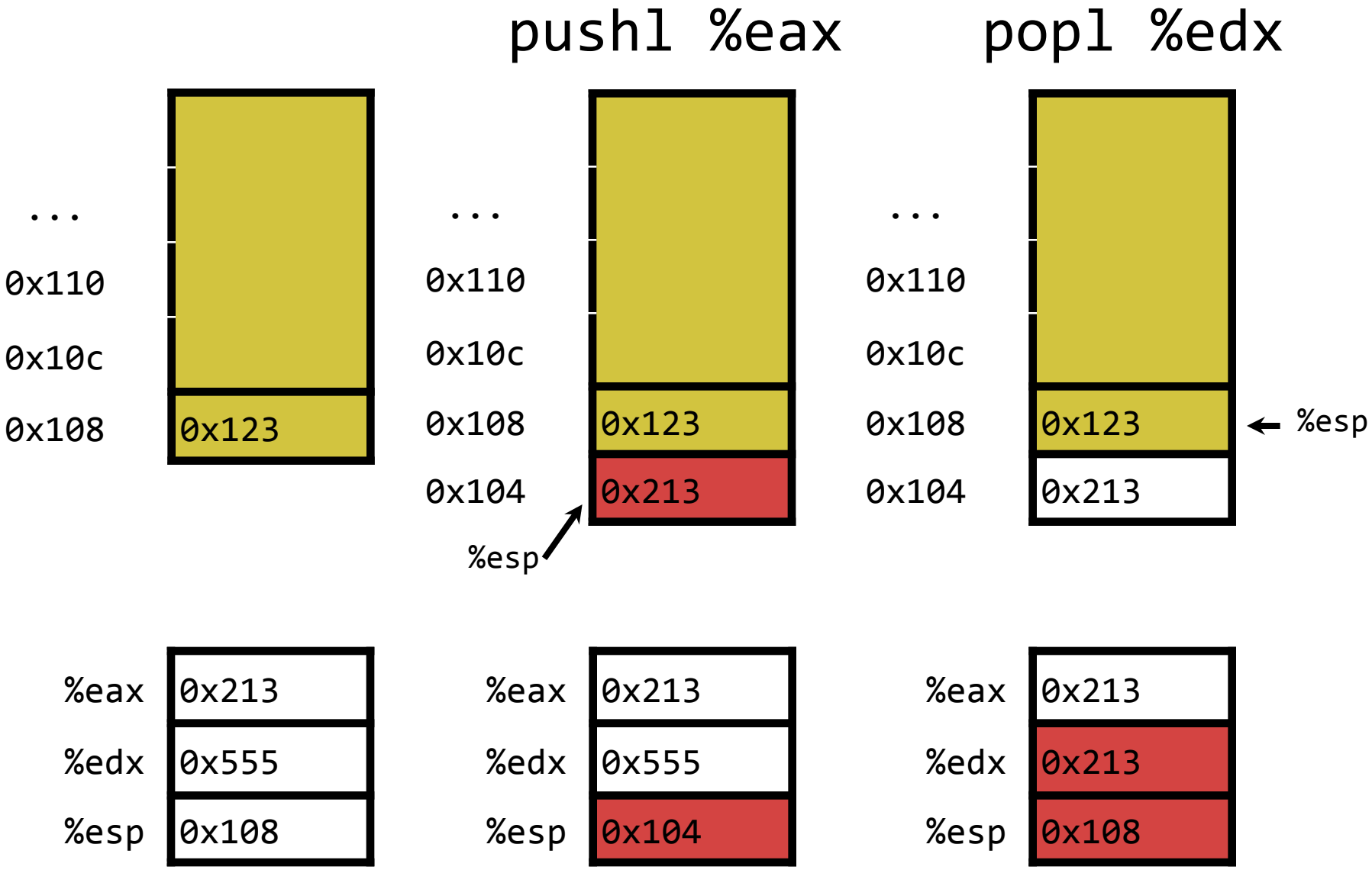
- It may be helpful to remember this correspondence (IA32)
  - Note: This is probably not how it actually works

```
pushl src  ──────→  subl $4,%esp
                    movl src,(%esp)

popl dest  ──────→  movl (%esp),dest
                    addl $4,%esp
```

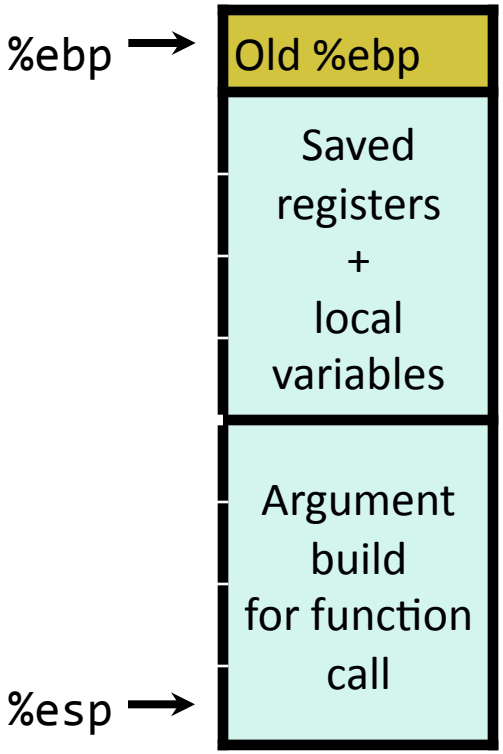
- %esp "points" to the top value on the stack

Quick example



Stack frames

- Every function call is given a stack frame
- What does a C function need?
  - Local variables (scalars, arrays, structs)
    - Space for scalars if the compiler couldn't allocate enough registers
  - Space to save callee saved registers
  - Space to put computations/temporaries
  - A way to give arguments and call other functions
  - A way to grab arguments
- We can do all these things with the stack!

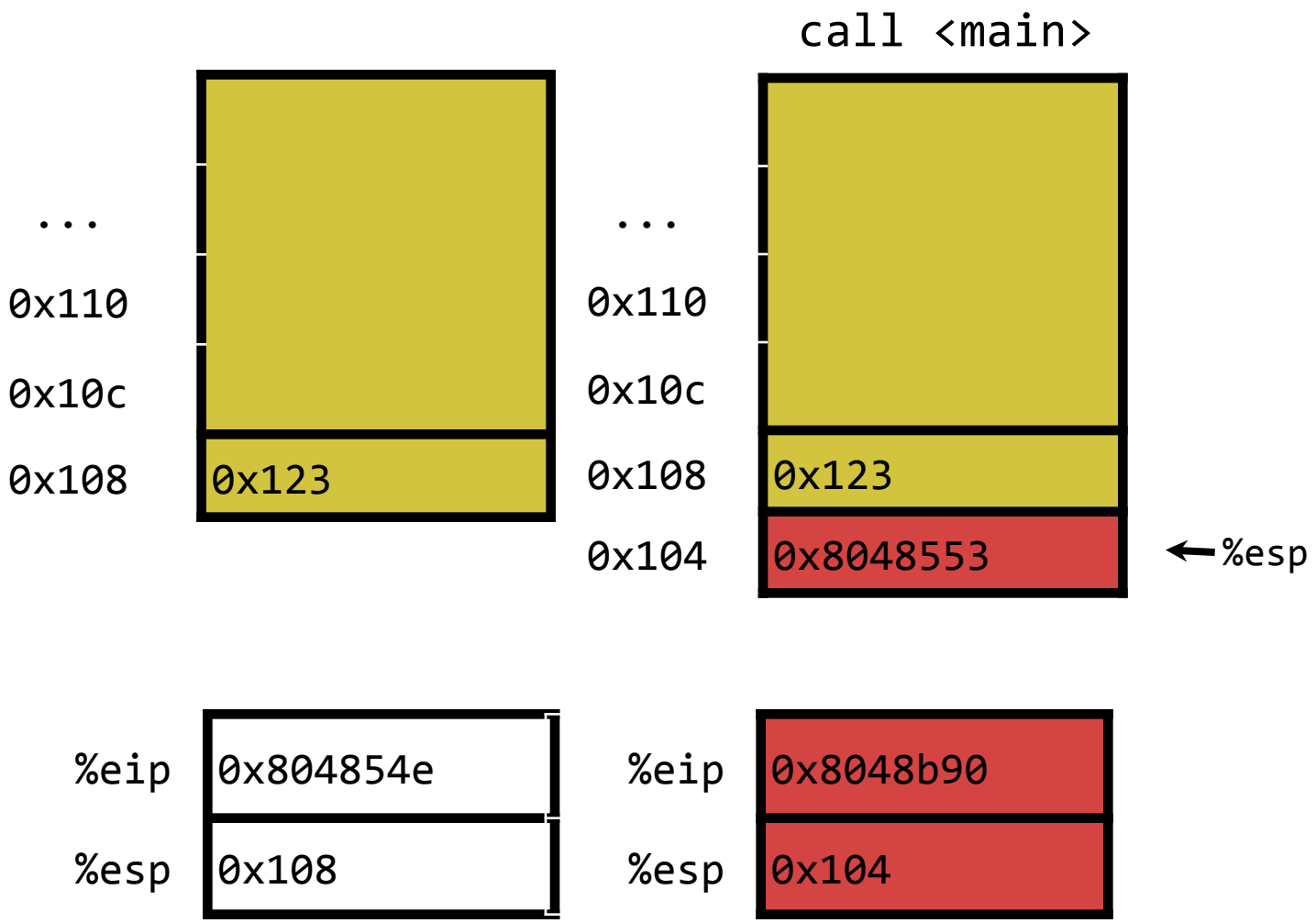


Function calls

- Use the stack for function calls
- Function call
  - `call label` Push "return address" on stack, jump to label
- Return address?
  - Address of the instruction immediately after the `call`
  - Example from disassembly:
    - `804854e: e8 3d 06 00 00  call 8048b90 <main>`
    - `8048553: 50  pushl %eax`
  - Return address is `0x8048553`
- Returning from a function call
  - `ret` Pop return address [(%esp)] into %eip, keep running
  - Remember that the function's actual return value must be in %eax

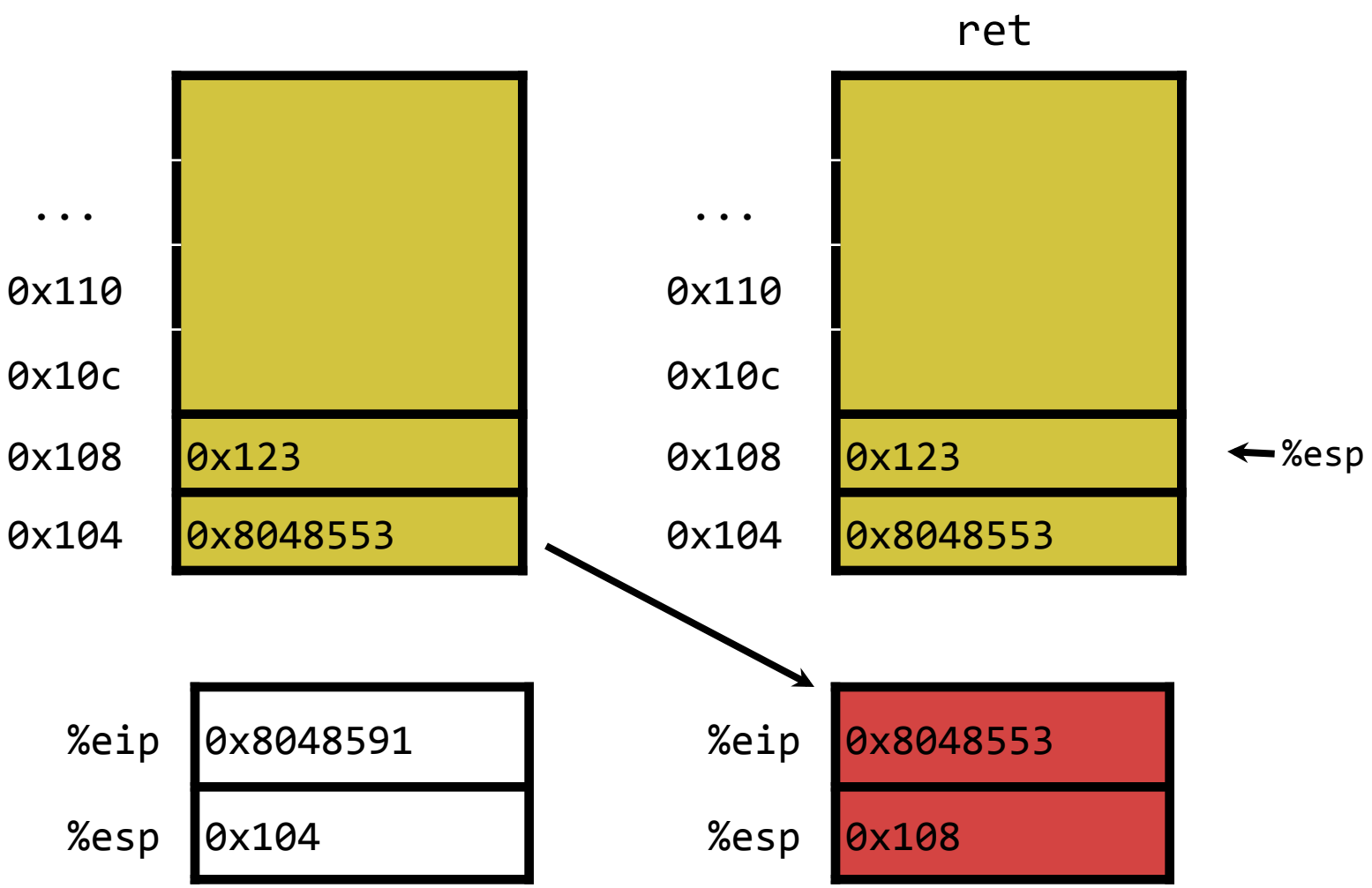
What does this look like?

- `804854e: e8 3d 06 00 00  call 8048b90 <main>`
- `8048553: 50  pushl %eax`



Returning

- 8048591: c3 ret

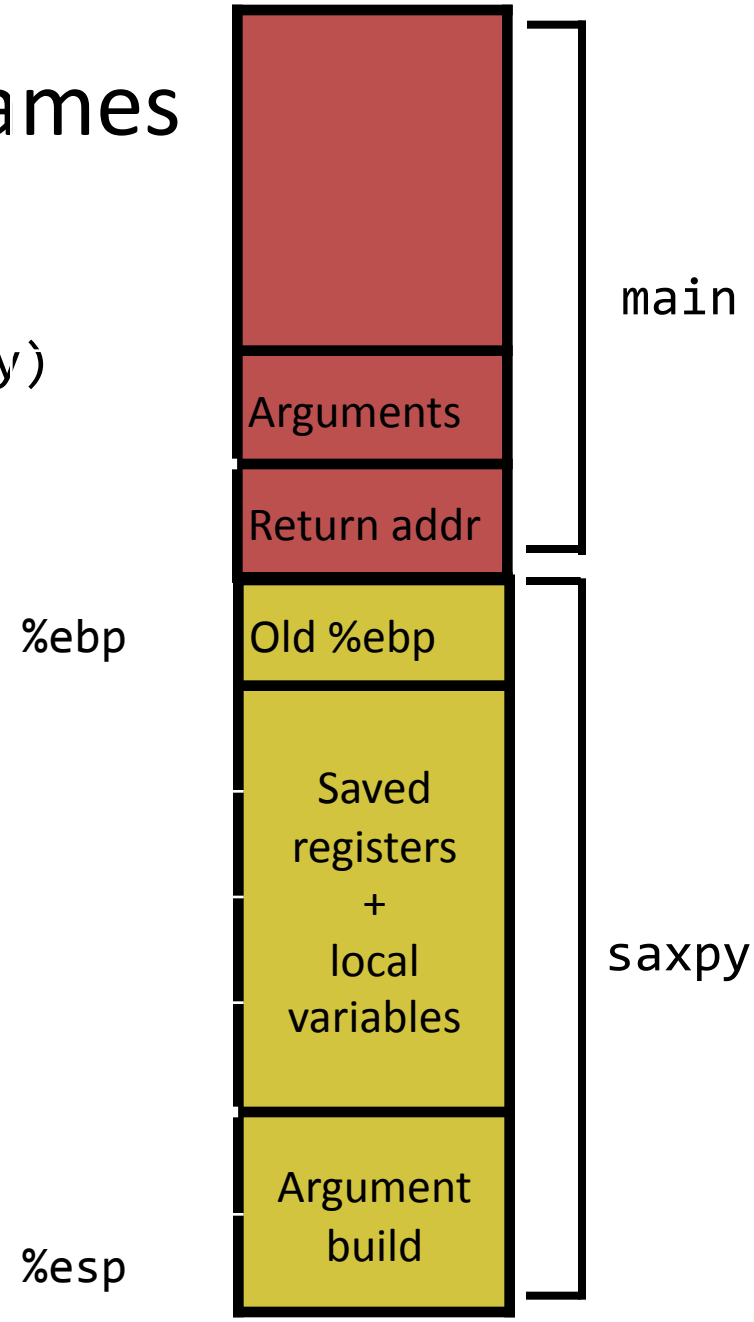


Function calls and stack frames

- Suppose you have

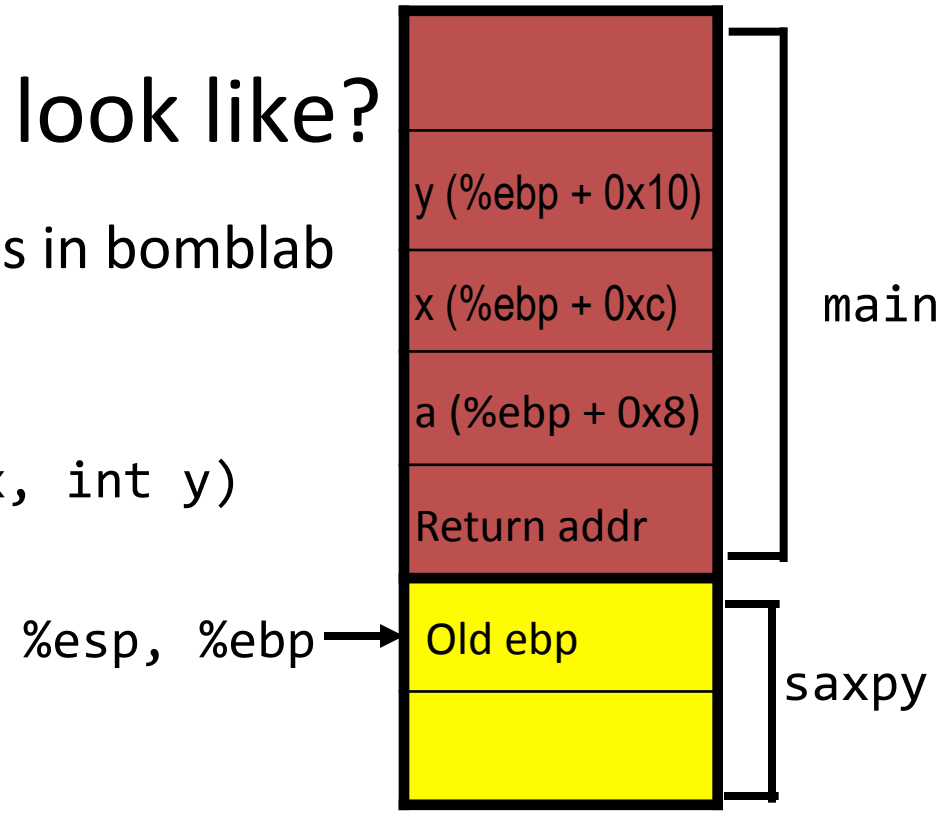
```
int scalar_saxpy(int a, int x, int y)
{
    return a * x + y;
}
int main(void)
{
    int x = 3, y = 4, a = 5;
    return scalar_saxpy(a, x, y);
}
```

- In IA32 we pass arguments using the stack
- scalar_saxpy grabs arguments by reaching up the caller's stack frame!



What exactly does this look like?

- Hint: You have probably seen this in bomblab




```
int scalar_saxpy(int a, int x, int y)
{
    return a * x + y;
}
```

```
08048374 <scalar_saxpy>:
 8048374:       55              push   %ebp
 8048375:       89 e5           mov    %esp,%ebp
 8048377:       8b 45 08        mov    0x8(%ebp),%eax    # Move a to %eax
 804837a:       0f af 45 0c     imul   0xc(%ebp),%eax    # Multiply x with a
 804837e:       03 45 10        add    0x10(%ebp),%eax   # Add y to a*x
 8048381:       5d              pop    %ebp
 8048382:       c3              ret
```

Stacks/Functions on x86-64

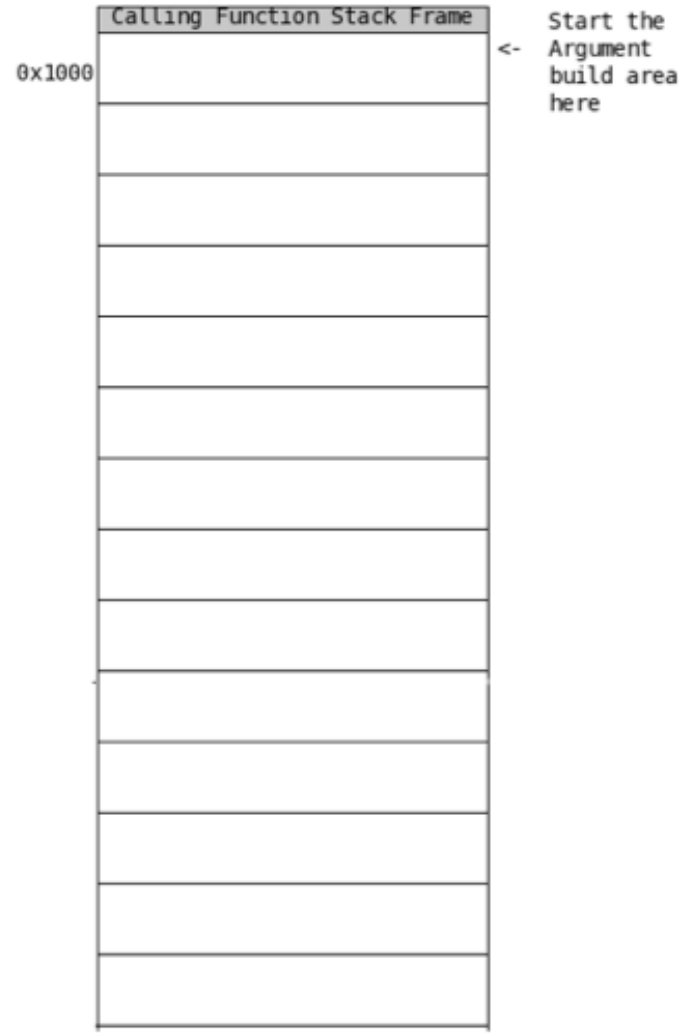
- Everything is even easier
- Arguments (≤ 6) are passed in registers
  - `%rdi, %rsi, %rdx, %rcx, %r8, %r9`
  - Extra arguments are still passed on stack – IA32 knowledge is still useful!
- We have nicer compilers now – don't need `%rbp`
- Overall less stack usage - potentially better performance
  - See memory hierarchy
- You are expected to know how 64-bit stacks work
  - Even if there are no labs on it

Example (from a 213 exam I took)

- Given the following function prototypes, and initial lines of IA32 assembly for each function, fill in the stack frame diagram with
- registers to be saved
- any arguments to the function `foo`
- the return address
- Any registers stored on the stack by the asm fragment
- The location on the stack pointed to by %esp and %ebp after execution of the `sub` instruction

```
int foo(int a, int b, int c, int d);
push %ebp
mov  %esp,%ebp
push %ebx
sub $0x10,$esp
```

- (Bonus: How does `foo` access its arguments after the `sub`?)



But what about floating point arguments?

- It's complicated
- You don't need to worry about it
- In some chips there is a separate floating point stack (!!)
- Example of complication
  - In x86-64 the stack on function entry needs to be 16-byte aligned if a function will need to use floating point (??)
  - Many, many more tricky things to know

Questions?

(stacks, bomblab, what is buflab)

(come to office hours if you need help)